Site Selection for Landfills

Module-III

Methodology

- Estimate the size of landfill required
- undertake constraint mapping
- list of potential sites
- preliminary data collection
- Site walk over
- Site investigation
- Ranking of sites
- Public Acceptance
- Regulatory Approval

Location Criteria (for lined landfills)

Lake/pond	:	>200 m (>500m DW)
River	:	>100 m
Flood plain	:	Protective Embankment
Highway	:	>500m
Habitation	:	> 500m
Public park	:	> 500m
Critical Habitat	:	NO
Wetland	:	NO
Coastal Regulation Zone	:	NO
Airport	:	>3000 m to 20km
Water supply well	:	>500 m
Ground water table level	:	2m below base of landfill
Others	:	Local needs

Components

(a) Liner System

(b) Leachate collection Facility

(c) Daily Cells

(d) Daily Cover

(e) Lift

(f) Phase (yearly)

(g) Intermediate cover

(h) Bench (Terrace)

(i) Final Cover System

(j) Gas collection Facility.

Landfill Capacity

Factors:

(a) Quantity of waste and its compacted density.

(b) Volume of waste

(c) Volume occupied by liner and cover (daily, intermediate, final)

(d) Volume reduction due to settlement.

Management of Emissions

Leachate :

a) Discharge to drain
b) Solar evaporation pond / Forced evaporation in incinerators or evaporation plants.
c) offsite treatment in ETP
d) onsite treatment in ETP
e) Recirculation.

(contd...) phased operation

d) During the monsoons the following methodology may be adopted.

(i) Landfill may be kept capped and non-operational; all waste may be stockpiled in a temporary holding area (covered with roof)

(ii) Special 'monsoon phases' may be designed in a separate area of the landfill to phase the waste. Such phases would have temporary mobile covers and a leachate collection system with high capacity.

Management of Emissions

Gas:

a) Allow slow advection / diffusion / dispersio
b) Passive vents
c) Collect and flare
d) utilise for cooking / heating
e) utilise for power generation.

Closure and post-closure plan

objectives:

- Ensure that all landfill components continue to remain functional for a long period (typically 30 years) after closure
- Achieve the intended end-use of landfill surface (e.g. golf course, parking area, restore to original condition)
- Effectively remove surface water.
- periodically inspect and prepare maintenance schedule.

Geotechnical Design of Components

a) Embankment Design
b) Liner design
c) Leachate wells & Drains
d) Cover design
e) Gas wells and Drains
f) Stability Analysis
g) Enviromental Moenitoring
h) Estimation of Quantities and Costs.

Liners For Landfills

Estimation of Landfill Capacity

Waste generation rate = w tons per year

Active life of landfill = n years

Total waste in n years (T) = $w \times n$ tons

w is not constant but increases with ~~the~~ time as population and per capita waste generation (WG) increases.

Future pop = Current pop $(1 + y/100)^n$

($y \sim 1.2\%$ India, -0.1% Japan, 0% Germany))

Future WG = Current WG $(1 + \alpha(\text{GDP growth}) + \text{others})$

W_i = Future pop $\times$ Future WG for ith year

$T = \sum W_i$

Closure and post-closure plan

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  (e.g. golf course, parking area, restore to original condition)
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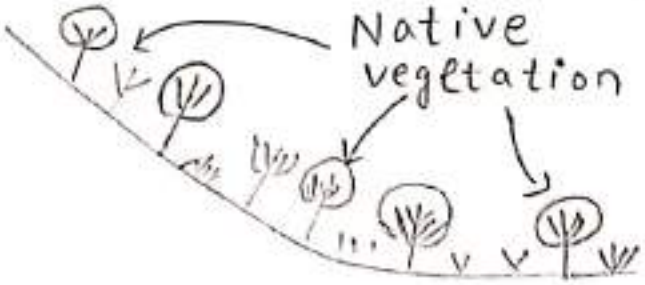
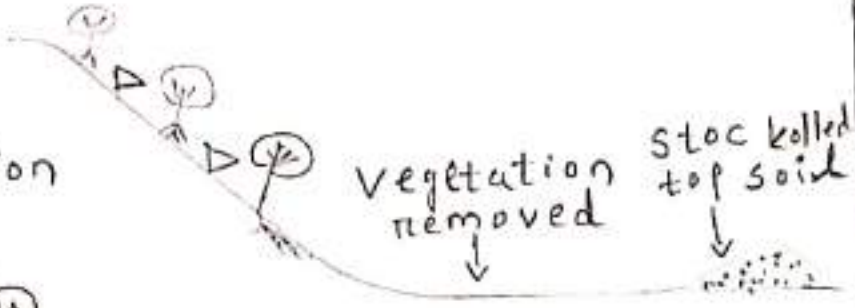
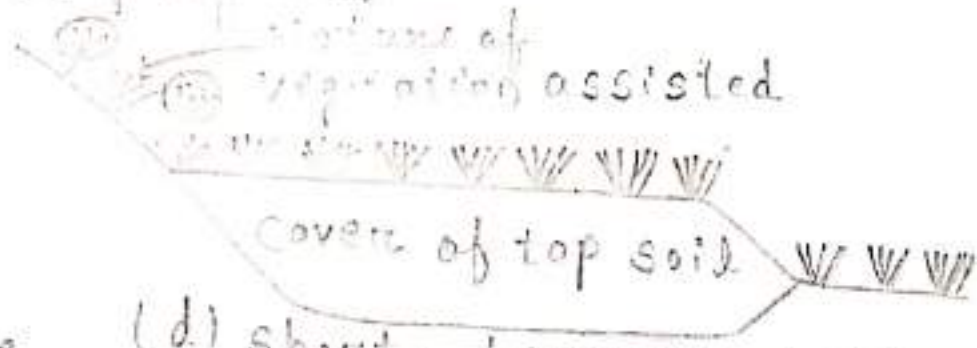


a) Original Landform

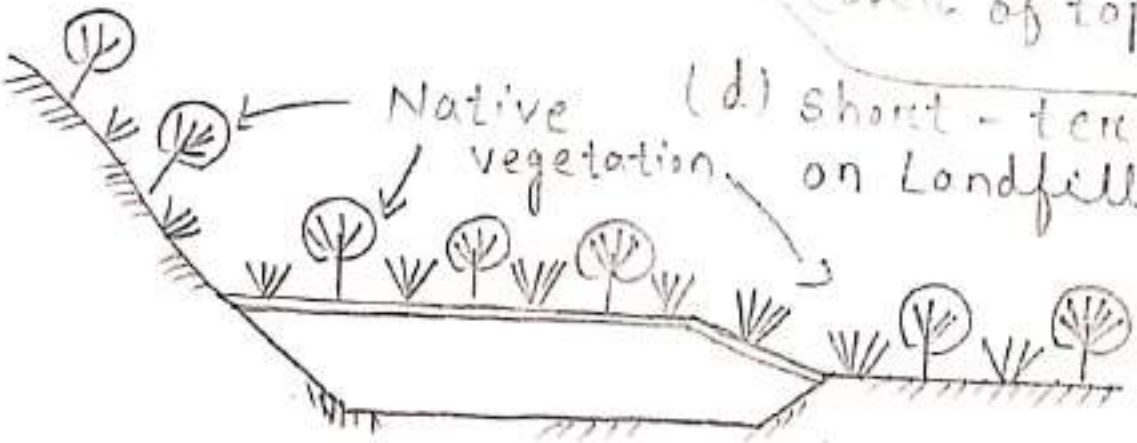


b) Excavation for Landfill

c) Landfilling in progress



(d) Short-term vegetation on Landfill cover.



(e) Long-term vegetation on Landfill cover.

Functional Requirements of Barrier Layer in liner systems.

- should be impervious (very low permeability)
- should remain intact under settlement of subsoil (high flexibility and high strength)
- should remain functional for the designed life of landfill i.e. 50 to 100 years in saturated/moist and chemically aggressive environment:
- should not be affected by leachate
- should not degrade with time (non-biodegradable, U.V stability, oxidation)
- should not show long-term cracking.

Experience with Hydraulic Barrier Material:

Water storage tank: Concrete, steel, Polymers.

Canals & Ponds: Concrete, clay, polymeric membranes.

- Dams & Barrages : Concrete, clay, asphaltic membranes.
- Roof & Basements : Concrete, waterproofing materials, asphalt, asphaltic membranes.

Concrete :
- Rigid, thin, in-situ construction, joints, cracks

Steel / Aluminium Metal sheets :
- Rigid / flexible, thin, prefabricated, joining onsite, quality of joints, costs

Clay :
- Flexible, thick, in-situ Compaction, low permeability, shrinkage cracks (reversible)

Problem with thin polymeric membranes
- Leakage through puncture or tearing
- Leakage through joints
- Fast seepage through small holes.

Problem with thick clay barrier

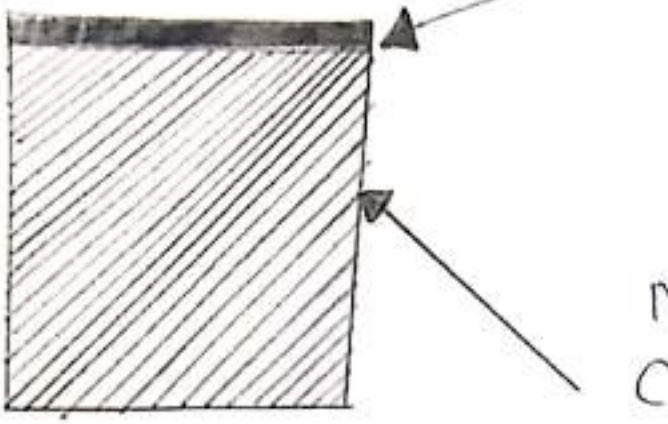
- Not totally impervious
- Heterogeneity
- Shrinkage cracks (reversible)
- Slow seepage through large area.

Polymeric Membranes :
flexible, thin, prefabricated, joining on site, quality of joints, puncture, tear.

Asphaltic Materials :
Flexible, thin, construction at site or prefabricated, quality of construction, require strong base.

Waterproofing Materials (resins, polyurethane etc.)
flexible, thin, application on site, require strong base.

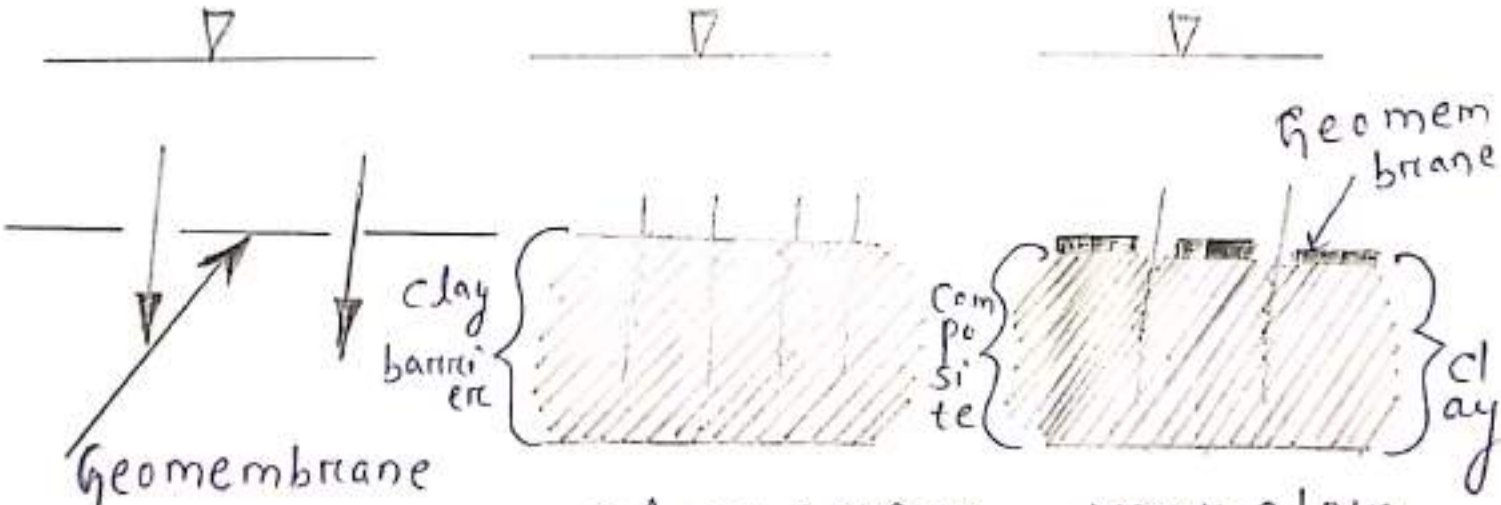
Composite Barriers :



HDPE Geomembranes
1·5mm to 2·5 mm thick

Natural clays
Compacted clays
Compacted IN-Situ Soil + clays

$K \leq 10^{-9}$ m/sec
> 100 cm



Rapid seepage through small punctures

Slow seepage through large area

very slow seepage through small area.

Composite barrier

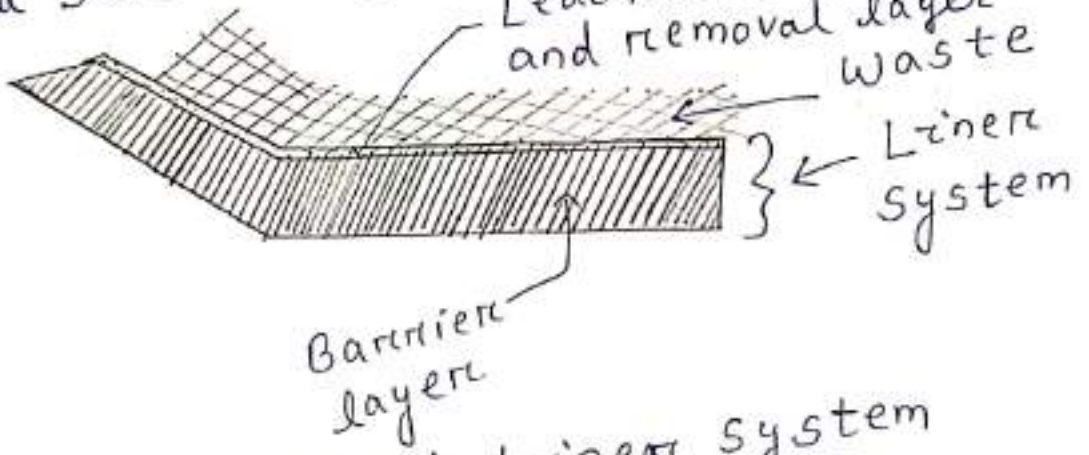
- Polymeric membrane in intimate contact with clay barrier.
- Seepage through holes in geomembrane intercepted by clay barrier.
- Geomembrane of adequate thickness to prevent puncture or tear.

Liner Systems

- Single liner system :
- used in canals, ponds, lakes
- Single Composite liner system :
- Used in landfills, Comprises of single leachate collection layer and Single Composite barrier layer.
- Double liner System :
- Double walled underground tanks
- Double Composite liner System :
- Used in landfills
- Comprises of primary and secondary leachate

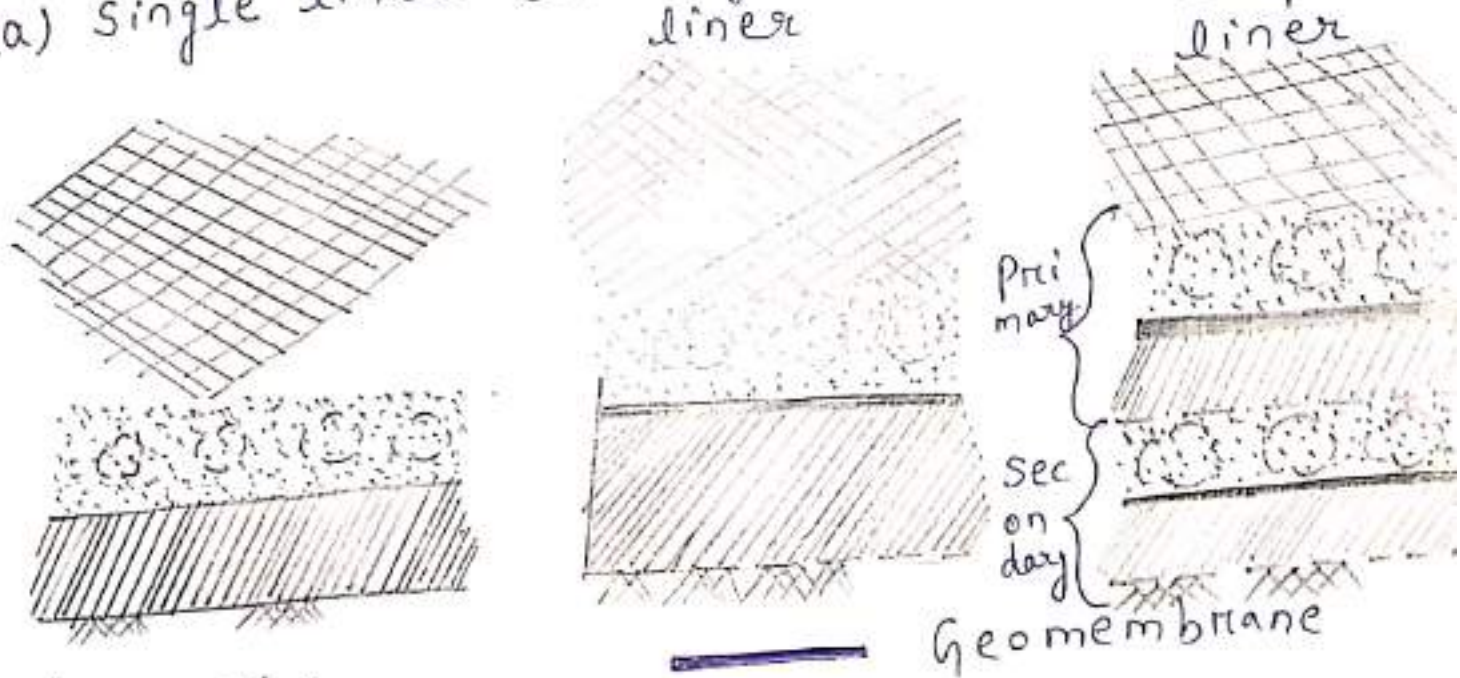
Collection systems as well as Primary & Secondary Composite barrier layers

- Secondary leachate collection system is also called the leakage detection layer.



A Typical Liner system

(a) single liner (b) Single Composite liner (c) Double Composite liner



waste

Barrier Clay

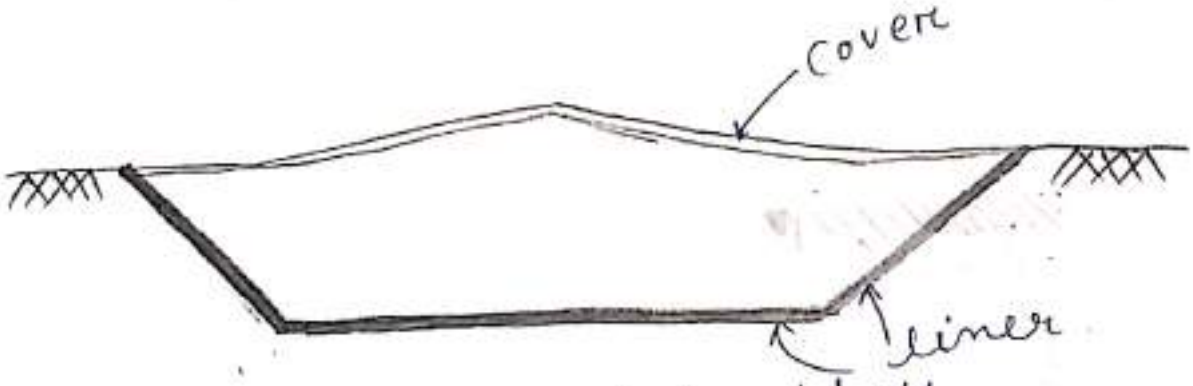
Subgrade

Separator / protector

Perforated pipe

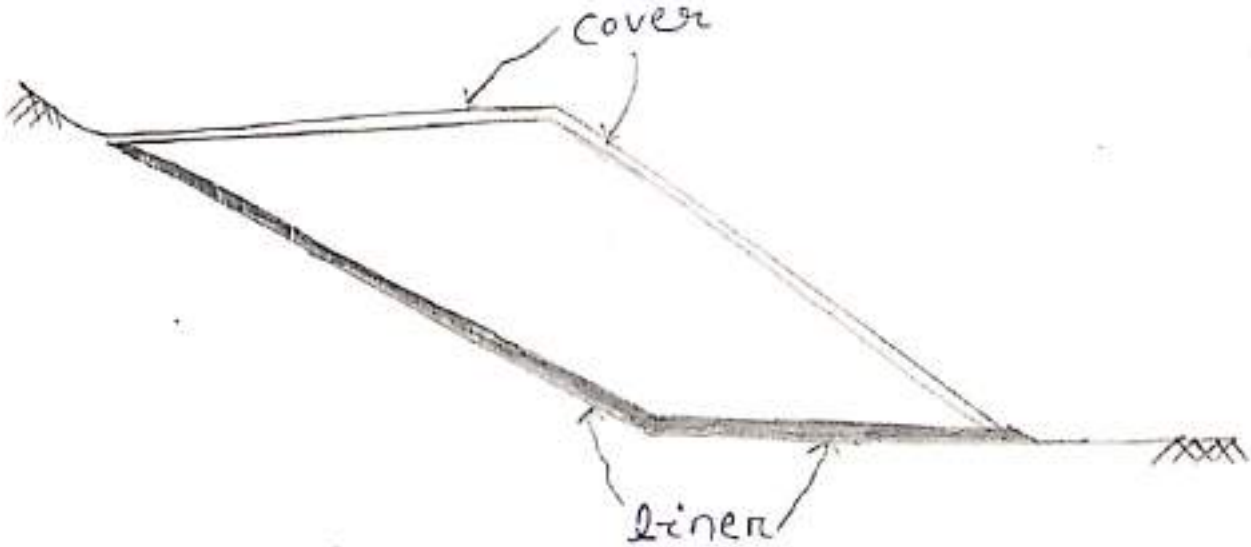
Drainage layer

Liners of landfills



(a) Below ground landfill

(b) Above ground landfill



(c). Side slope landfill

Liners and covers of landfills

Composite Barriers :

HDPE Geomembranes
1.5 mm to 2.5 mm thick

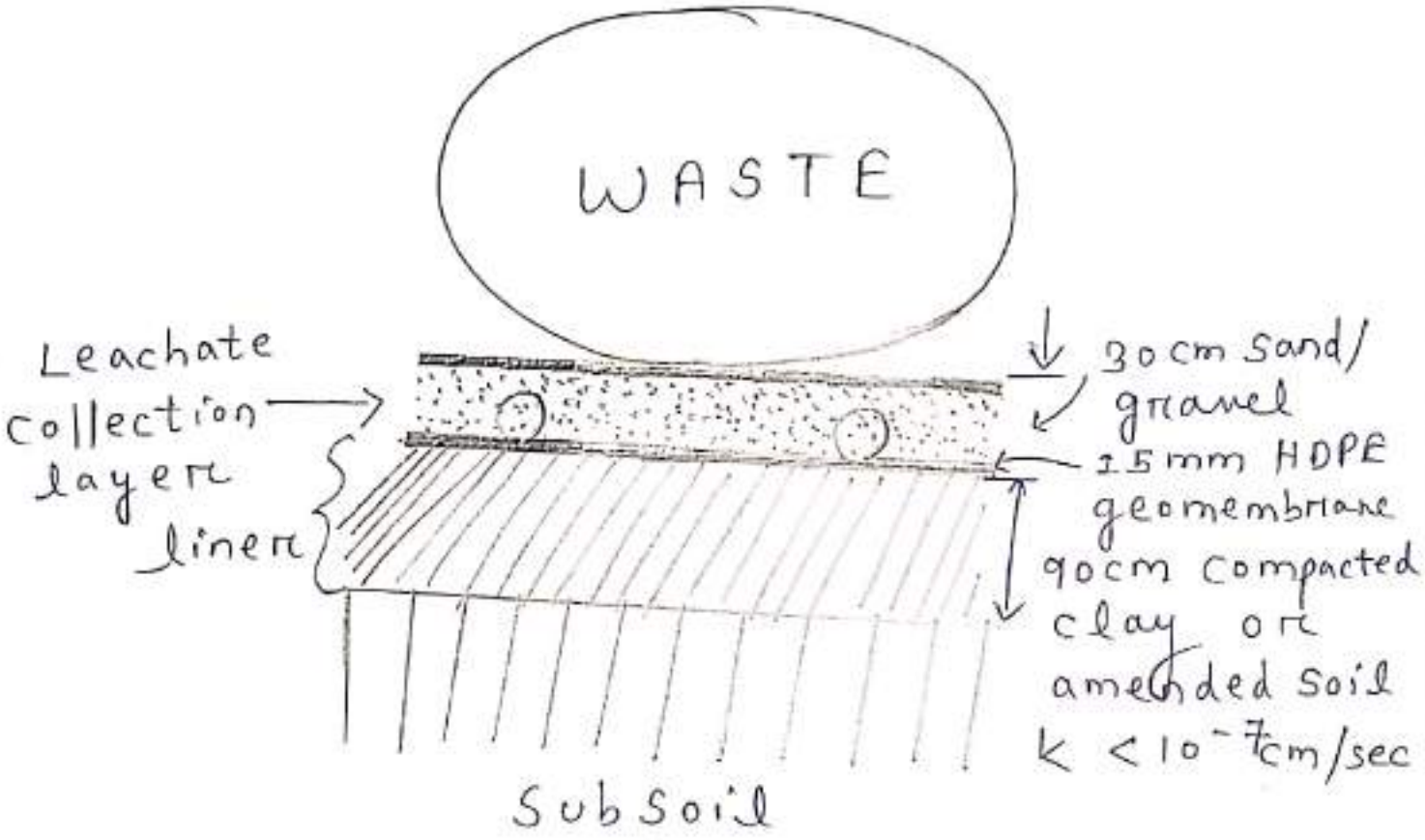
Natural clays
Computed clays
Compacted In-situ Soilt clays.

$K \leq 10^{-9}$ m/sec

> 100 cm

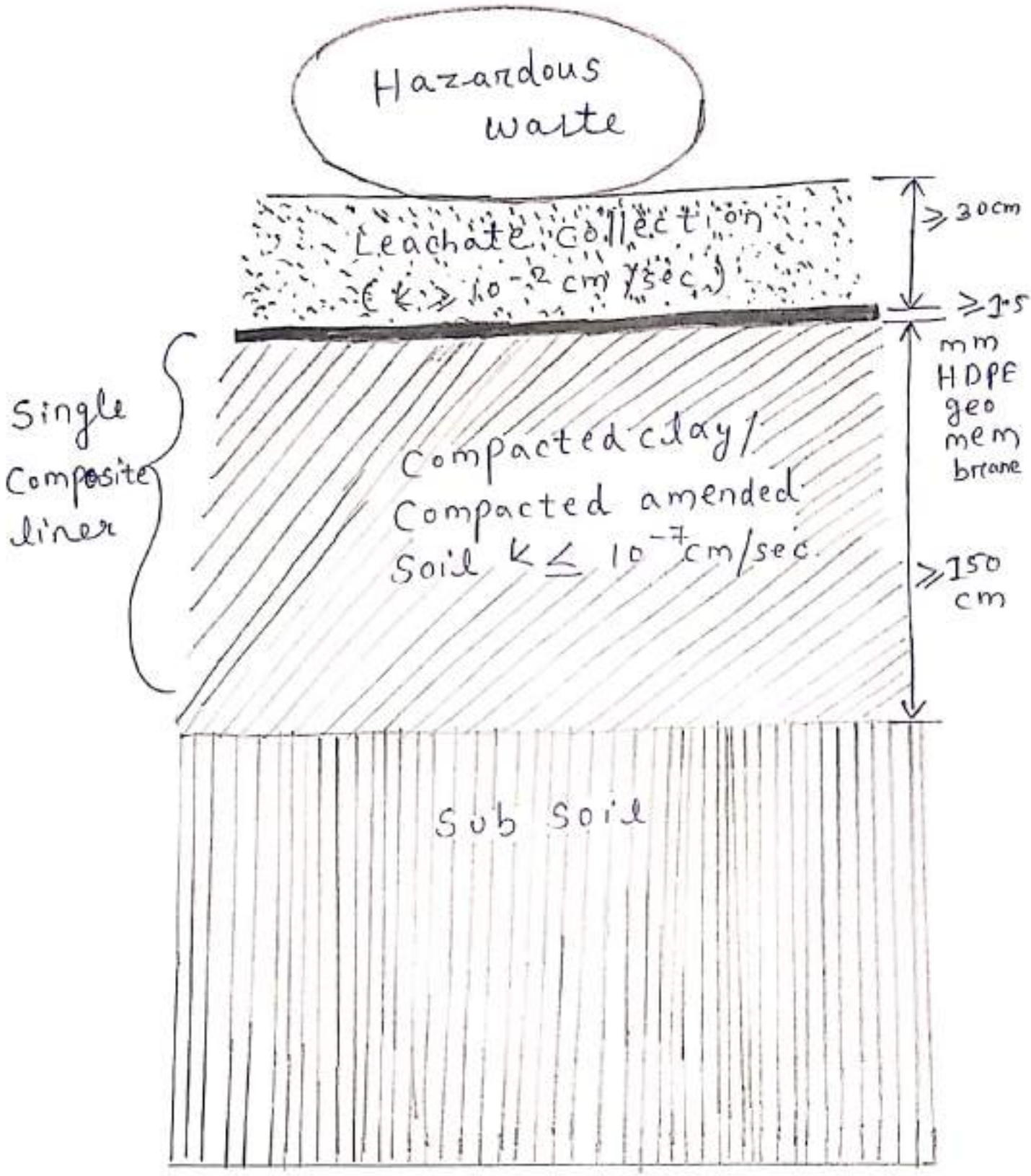
Linear Systems

- Single linear System :
- used in Canals, ponds, lakes
- Sometimes for C&D waste landfill
- Single Composite linear System :
- used in non-HW landfills, Comprises of single leachate collection layer and single Composite barrier layer.



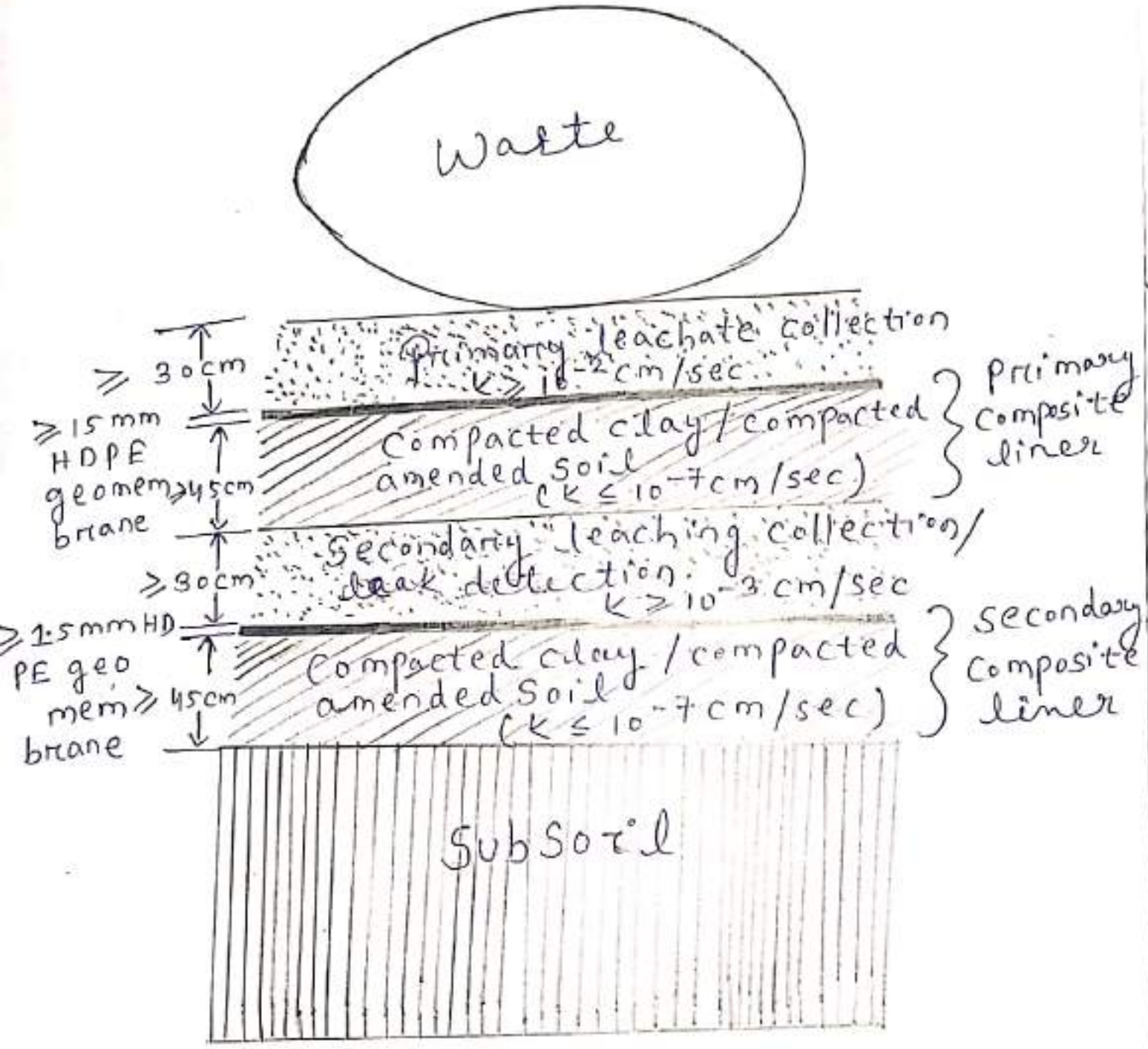
Liner system

Liner for MSW Landfill (India)



Single composite liner system (CPCB - 2001)

Hazardous waste landfill (India)



Double Composite liner system
(CPCB - 2001)

Hazardous Waste Landfill
(India)

Double over Single ?

- When risk is high eg HW over MSW
- When WT is shallow
- When Sub-soil is pervious
- When precipitation is high
- When a drinking water source (eg wells, or lake) is very near
- When 100% leakage detection is required.

Filter, Separator, Protector

- Many interfaces between different layers
- Filter: allows water to pass without fines of soil

Separator: does not allow particles of one soil to mix with another soil across the boundary of an interface

Protector: prevents puncture or tear or damage of underlying material (sacrificial layer)

Requirement of filter / separator / protector

a) Between waste overlying leachate collection layer : Fine particles of waste should not clog the sand / gravel of the lower layer - filter layer required

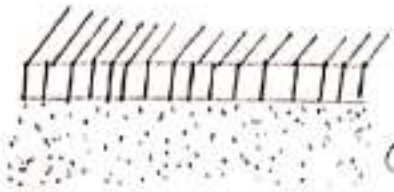
b) Between leachate collection layer overlying geomembrane : the gravel / sand particles with angular corners should not puncture the geomembrane - protection layer may be required

c) Between compacted clay overlying secondary leachate collection layer or overlying subgrade : clay particles should not enter in to the sand / gravel of lower layer - filter / separator layer may be required.

Geotextiles (non-woven; 400gsm or more) or soil layers (15 to 25 cm thick having specific grain size distribution) can function as filters / separators / protectors.

Filter criteria

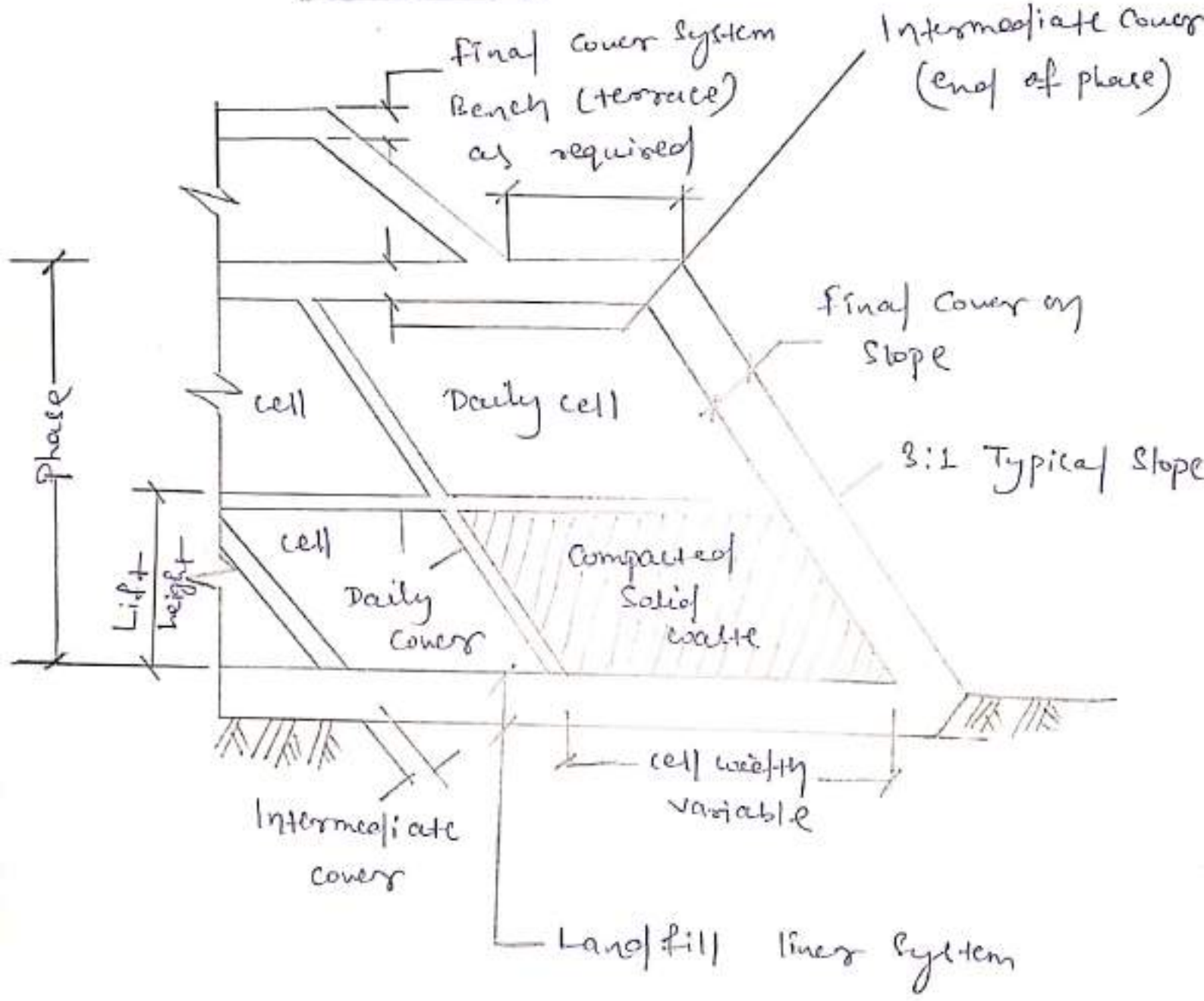
(a) No Filter



(b) Filter layer present

- A transition filter layer is provided bet^n soils having vastly differing particle sizes
- The filter allows unhindered flow of water but prevents fine particles from migrating through it
- Filter criteria
- $(D_{15}$ of filter$)/(D_{15}$ of protected soil$) >$ 3 to 5
- $(D_{15}$ of filter$/D_{85}$ of Protected soil$)$ < 3 to 5 .

planning of landfills



Landfill Details

Generation and Control of Leachate

Covers for Landfills

Surface Layer

- Top soil with grass
- Artificial turf
- Geosynthetic mats
- Rubble masonary
- Cobbles
- Paver blocks
- Others : Geocells with soil etc

Leachate generation and control

- Leachate Quality
- Leachate Quantity
- Leachate control with Liners
- Leachate Drainage and Collection
- Leachate Treatment

Leachate Quality

- The important factors which influence leachate quality include waste composition, elapsed time, temperature, moisture and available oxygen
- Leachate quality varies significantly over a period of time; leachate quality reaches a peak value after a few years and then gradually declines.
- The availability of oxygen has notable effect on biodegradable waste. Chemicals released due to aerobic decomposition are different from those released due to anerobic decomposition. Landfill conditions are anaerobic.

Barrier Layer

- Clay
- GM underlain by clay
- GM underlain by Geosynthetic Clay Liner

Gas Collection Layer

- Sand & Gravel
- Geocomposite
- GM essential for gas collection (optional for venting)

Foundation Layer

- Local Soil

Cover design Aspects

- Components and their specifications
- Thicknesses of components
- Separators, protectors, fillers
- Stability of slopes
- Erosion control
- Surface water drainage
- Gas collection
- Settlement / Subsidence

Assessment of Leachate Quality

- Laboratory tests:
  (a) Water percolation through waste and
  b) acidified water percolation through waste
- Samples from old waste dumps:
  involves driling and sampling
- Leachate after one year of operation of new landfill

Leachate Quality (Generation)

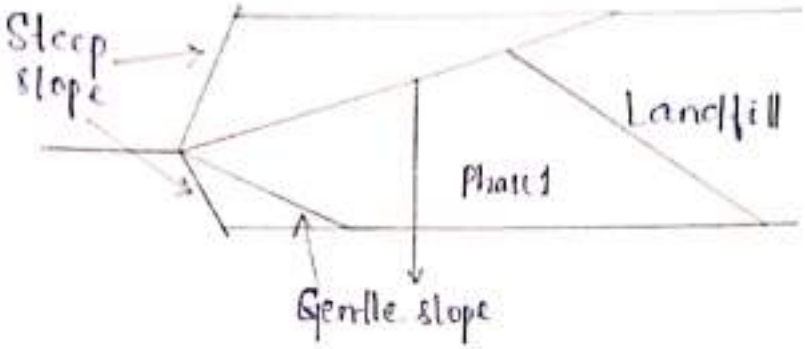
During Operation of landfill

- Almost all the precipitation that falls on operating (active) area infiltrates into the waste
- Some evaporates
- Some water held in the voids of the waste
- Balance becomes Leachate
- Some pore squeeze liquids also add to the leachate

Leachate Generation

- After closure of landfill phase
  - final cover placed on the waste
- Most of the precipitation that falls on the cover become surface runoff or evapotranspirates
- A small portion of precipitation infiltrates
- Quality of leachate very small.

Cover slope



(a) Excavated soil slope — 1.5 to 2.5 : 1.0
(b) Waste slope — 2.0 to 3.0 : 1.0
(c) Sliding along liner — 3.0 to 4.0 : 1.0
(d) Sliding along cover — 3.5 to 5.0 : 1.0

Geogrid and Geocell may be used to steepen slopes

Leachate Generation

During operation:

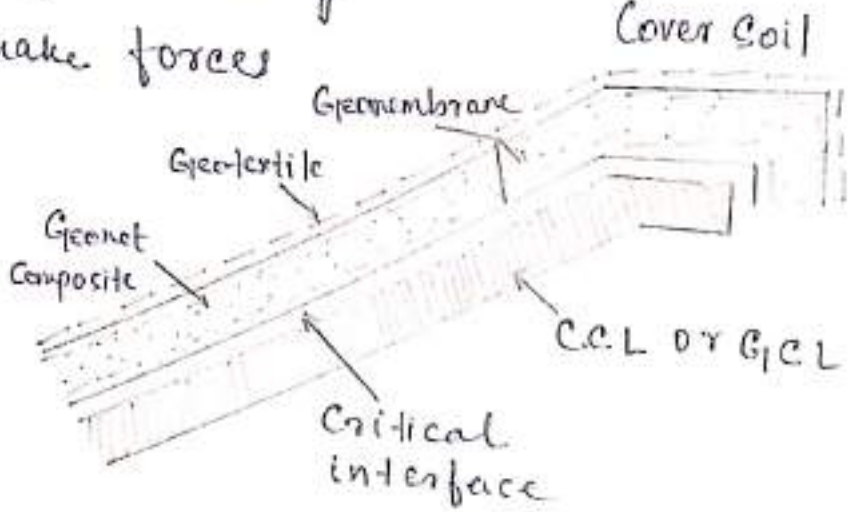
Leachate volume = (volume of precipitation) - (volume of pore squeeze liquid) - (volume lost through evaporation) - (volume of water absorbed by the waste)

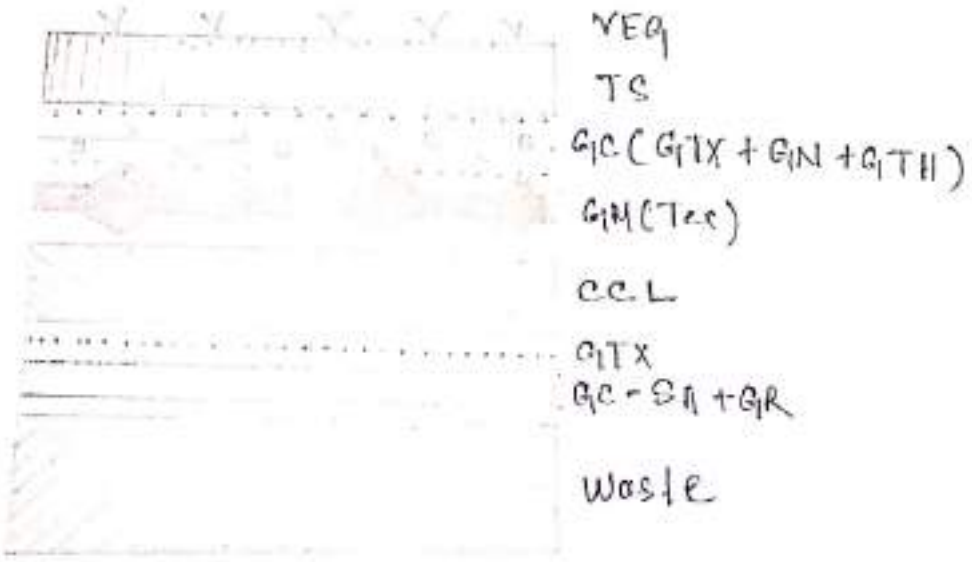
After closer:

Leachate volume = (volume of precipitation) - (volume of surface runoff) - (volume lost through evapotranspiration) - (volume drained through drainage layer above barrier) - (volume of water absorbed by waste and intermediate soil covers) + (residual volume of pore squeeze liquid)

Instability of slopes

- Slope inclination
- Low interface shearing resistance
- Large thickness of sloping soil / waste
- Vehicle braking during construction / maintenance
- Seepage force during rains
- Earthquake forces
- Others

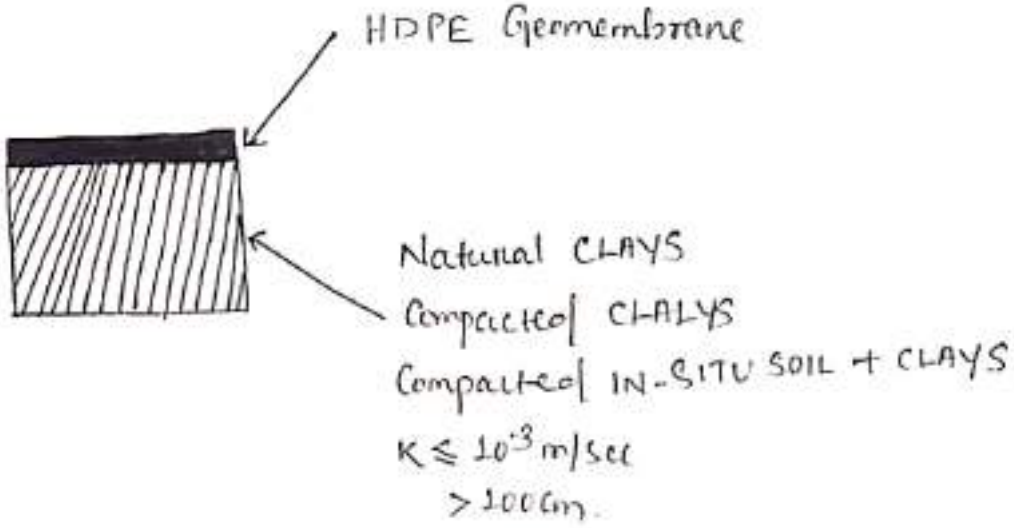




- Cover System A with Geocomposite Drain Replacing the sand drain

Liners For Landfills

Composite Barriers:



Options

(a) Insitu clay, excavated and recompacted
(b) Imported clay from nearby area (20 to 50 Km)
(c) Amended Soil - insitu soil mixed with 5% to 15% Commercial clay (bentonite)
(d) Imported clay from far off area

Steps:

Identify borrow area; perform laboratory tests; construct

Laboratory Tests on clay

(a) Classification - grain size distribution and plasticity
(b) Compaction - Standard Proctor Test (Light) or Modified Proctor Test (Heavy)
(c) Compaction Test on soil + Commercial clay (5, 10, 15, 20) (if required)
(d) Permeability - Flexible wall permeameter or rigid wall consolidation cell permeameter : on soil and [illegible] (if required)

Geomembranes

(a) Relatively thick HDPE sheet (1.5 to 2.5 mm)
(b) Flexible (high elongation at yeilol and break >50%)
(c) Heavy (1000 to 2500 gm per sq.m)
(d) Smooth or textured surface
(e) Resistant of puncture and tear
(f) Strong heat welding of seams
(g) Ultraviolet stability
(h) Wide (4 to 7m) and long (80m to 120m) rolls to minimize joints
(i) Resistant to more chemicals
(j) Other geomembrane materials are VLDPE, PVC, but HDPE is most popular

Installation of Geomembranes

(a) prepare panel Layout plan
(b) Installation preferable by manufacture
(c) Store the rolls in a dry, protected area
(d) Movement of rolls requires a light loader or fork lift.
(e) Unrolling by same equipment or manually
(f) Spotting and unrolling as per panel-layout plan.
(g) Before unrolling it is ensured that clay surface is smooth and all lumps, stones, protrusions are removed.
(h) Minimum overlap required for seaming is provided.

Quality Control of Geomembrane

a) Proper prequalification and selection of manufacture-cum-installer with experience of atleast 3 projects of similar size

b) Selected tests on geomembrane rolls received at site

(c) Field trial seams

(d) Destructive testing of seams

(e) 100 % non-destructive testing of seems

Testing of Rolls Received at Site

(a) One set of tests per 5000 sq.m or one set per lot (Consecutive rolls from same manufacturing line)

(b) Atleast two sets for each yearly phase and not less than five sets for the entire landfill

Field Trial Seams

(a) Test strips 1 to 2m in length constructed at site on spare pieces of geomembrane

(b) Destructive seam strength tests (shear and peel) conducted.

Destructive Testing of Field Seams

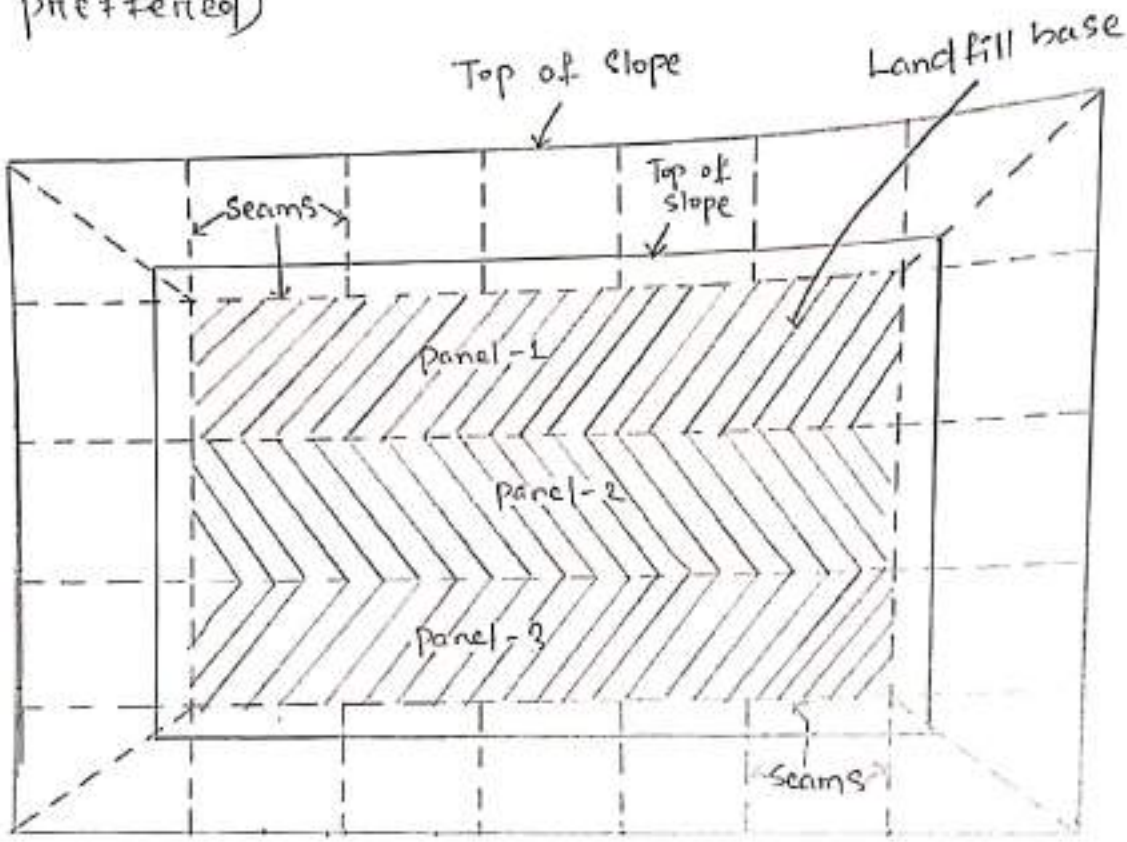
(a) for every 75 to 225 m of seam length in the field (typically 150 m) one patch of seam (30cm perpendicular x 70cm parallel) is cut.

(b) 10 samples tested in peel and 10 samples tested in shear.

(c) A new patch is installed to closed the hole created.

(Contd..) Installation of Geomembranes

(j) Thermal fusion of seams on extrusion welding executed by manufacturer (dual hot wedge is preffered)



Plan layout of geomembrane panels and seams

(Contd..) Installation of Geomembrane

(k) Construction details for seaming around pipes, sumps and vents provided by manufacturer

(l) Geomembrane anchored at top of side slopes to prevent slippage

(m) Geomembrane covered with soil (or protector) immediately after installation

(n) Soil should not be dropped directly on geomembrane by trucks but pushed forward by loaders.

(o) All staff should wear tennis shoes & not heavy construction boots.

(p) Installation during the coolest part of the day (mornings)

Geosynthetic Clay Liners (GCL)

(a) Commercial sodium bentonite sand enriched between or glued to geotextiles / geomembranes ($K = 10^{-10}$ to 10^{-12} m/sec)

(b) Advantage: factory manufactured clay + geosynthetic liner available in the form of rolls for easy installation

(c) Self healing properties of bentonite

(d) Very thin (~5 mm), hence enhanced landfill volume when it replaces 1m thick clay

(e) Easy installation along slopes

Geosynthetic Clay Liners (GCL)

(a) Works well when hydrated properly.

(b) Joints are by overlapping shrinkage can occur.

(c) Requires flat side slopes due to low hydrated shear strength of bentonite.

(d) Bentonite moves downwards along slopes if not held properly (internal erosion)

(e) Affected by dessication and cation exchange.

(f) Should not replace thick compacted clay in single composite liner or both thick clay layers in double composite liner.

(g) Can be used for replacing one of the clay layers in a double composite liner i.e geomembrane + GCL.

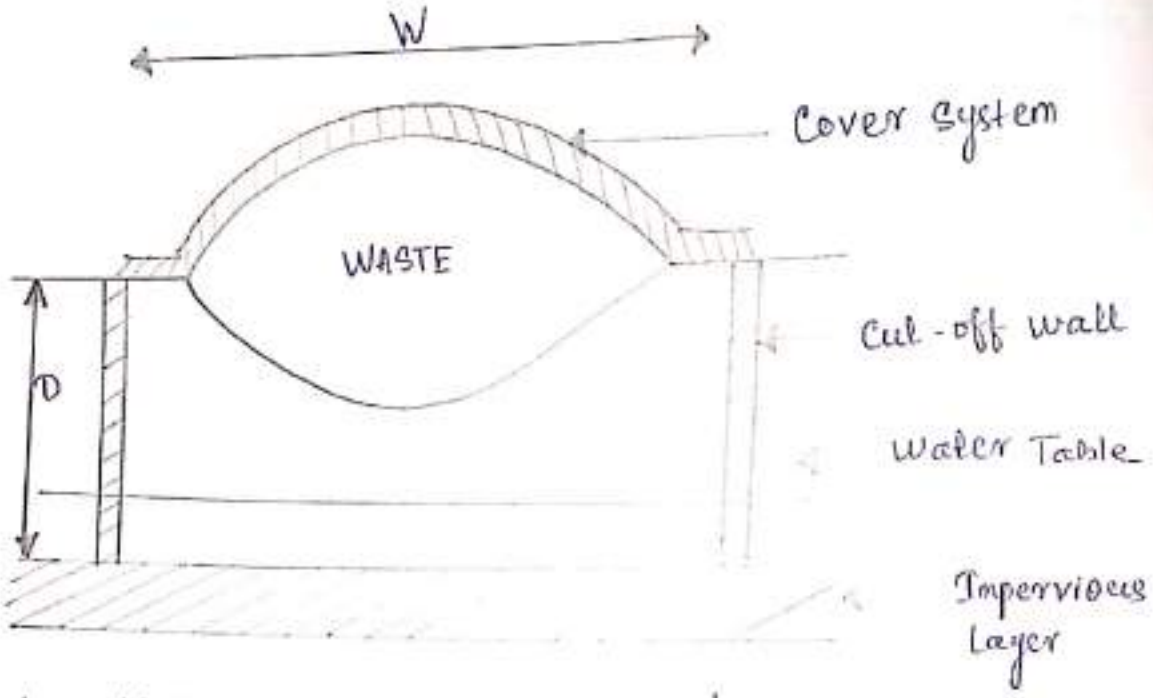
(h) Can enhance liner performance as an additional barrier layer if CCL permeability is not low enough.

Functional Requirements of Covers

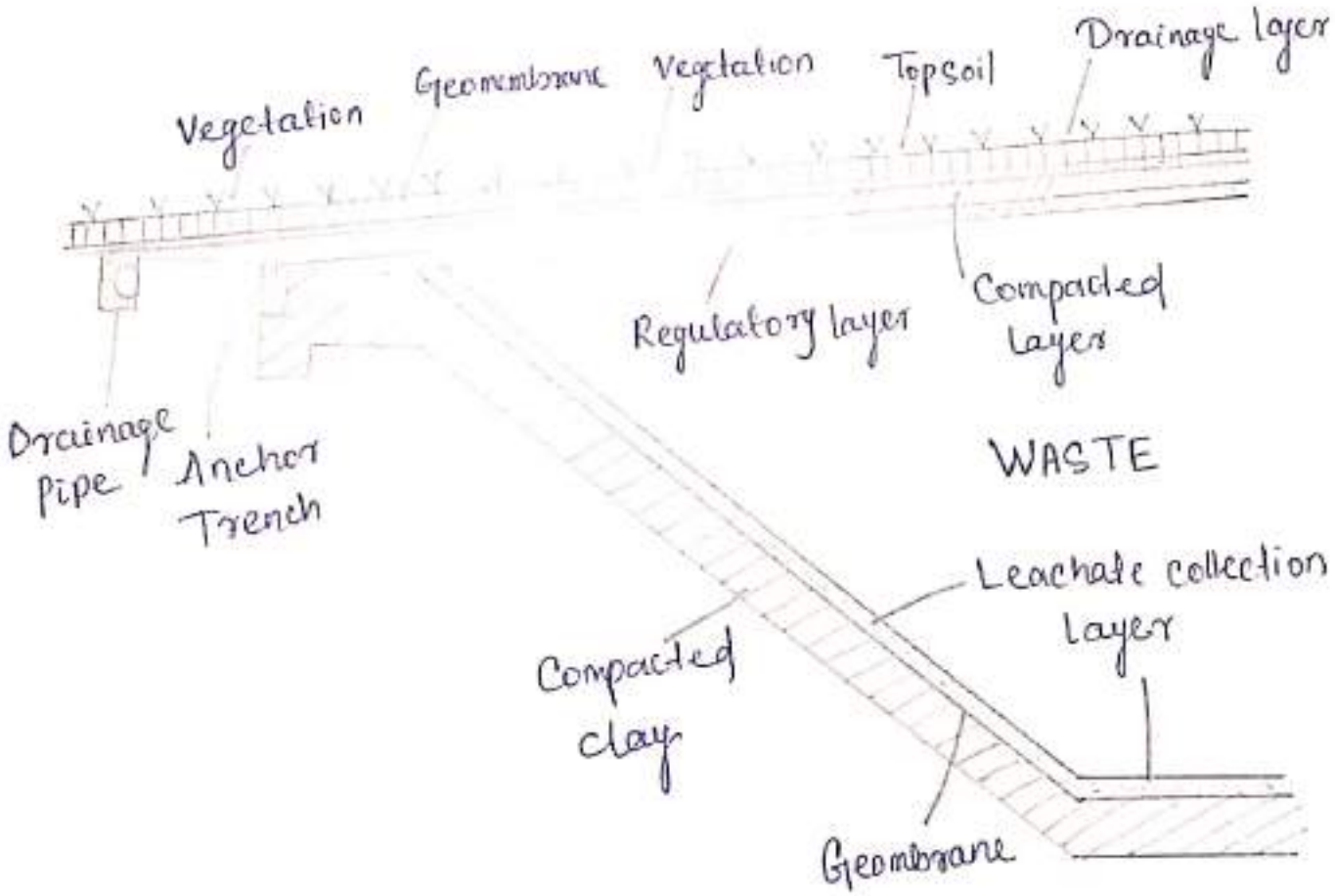
- Must minimise infiltration.
- Must act as hydraulic barrier (similar to that in a liner)
- Must prevent landfill gas from escaping.
- Must enhance surface runoff.
- Must prevent surface erosion.
- Must support vegetation.
- Must withstand long-term settlements.
- Must exhibit long-term slope stability.
- Must withstand surface exposure to loads (eg. traffic) and environmental conditions.

Comparision of liners and covers.

- Covers perform all the functions of liners and many more.
- Covers undergo much larger settlements than liners
- Covers have to drain off much large volume of water (precipitation) than the volume of leachate drained off by liners.
- Liners along side slopes, become buried with time, hence slope stability problem is temporary. Slopes of covers are permanent requiring long term stability.
- Covers are exposed to vagaries of nature - wind, rain, sun, snow, traffic, burrowing animals, plant roots etc.
- Covers are repairable, liners are not.



Old Landfill with Cover System and Vertical Cut-off Wall



Components of an Engineered Landfill

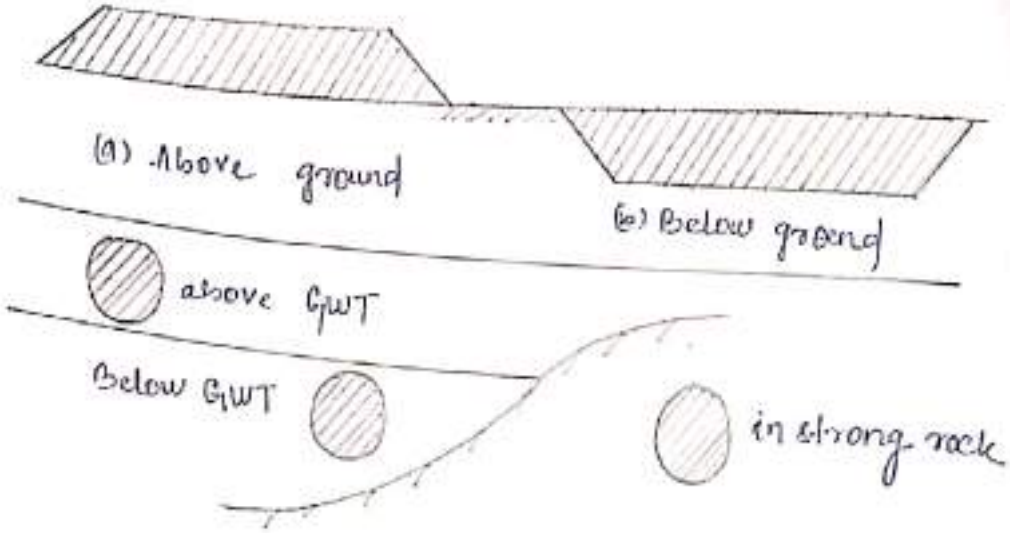
- A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil
- A leachate Collection Facility which collects and extracts Leachate from within and from the base of the landfill and then treats the leachate
- A gas Control Facility which collects and extracts gas from within and from the top of the landfill and then treats it, flares it or uses it for energy recovery
- A final Cover System which prevents migration of gas to the atmosphere, enhances surface drainage, intercepts infiltrating water and supports surface vegetation.

(Contd..) Components of an Engineered Landfill

- A surface water Drainage System which collects and removes all surface runoff from the landfill site
- An Environmental Monitoring system which periodically collects and analyses leachate, air, surface water, soil-gas and ground water samples around the landfill site
- A closure and post closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring and maintenance of the completed landfill (Typically 30 to 50 yrs

Options for Waste Landfilling

- Disposal on the ground surface
- Disposal deep below the ground surface



(c) Deep below ground

Waste disposal Options

Advantages of Above Ground Landfills:

- Drainage of leachate by gravity
- Large thickness of unsaturated zone below landfill
- Poor surface drainage can be avoided
- Easy inspection and maintenance

Disadvantages of Above Ground Landfill

- Land-use pattern altered
- More surface area exposed
- Slope stability and erosion control measures required

Advantages of below Ground Landfills:

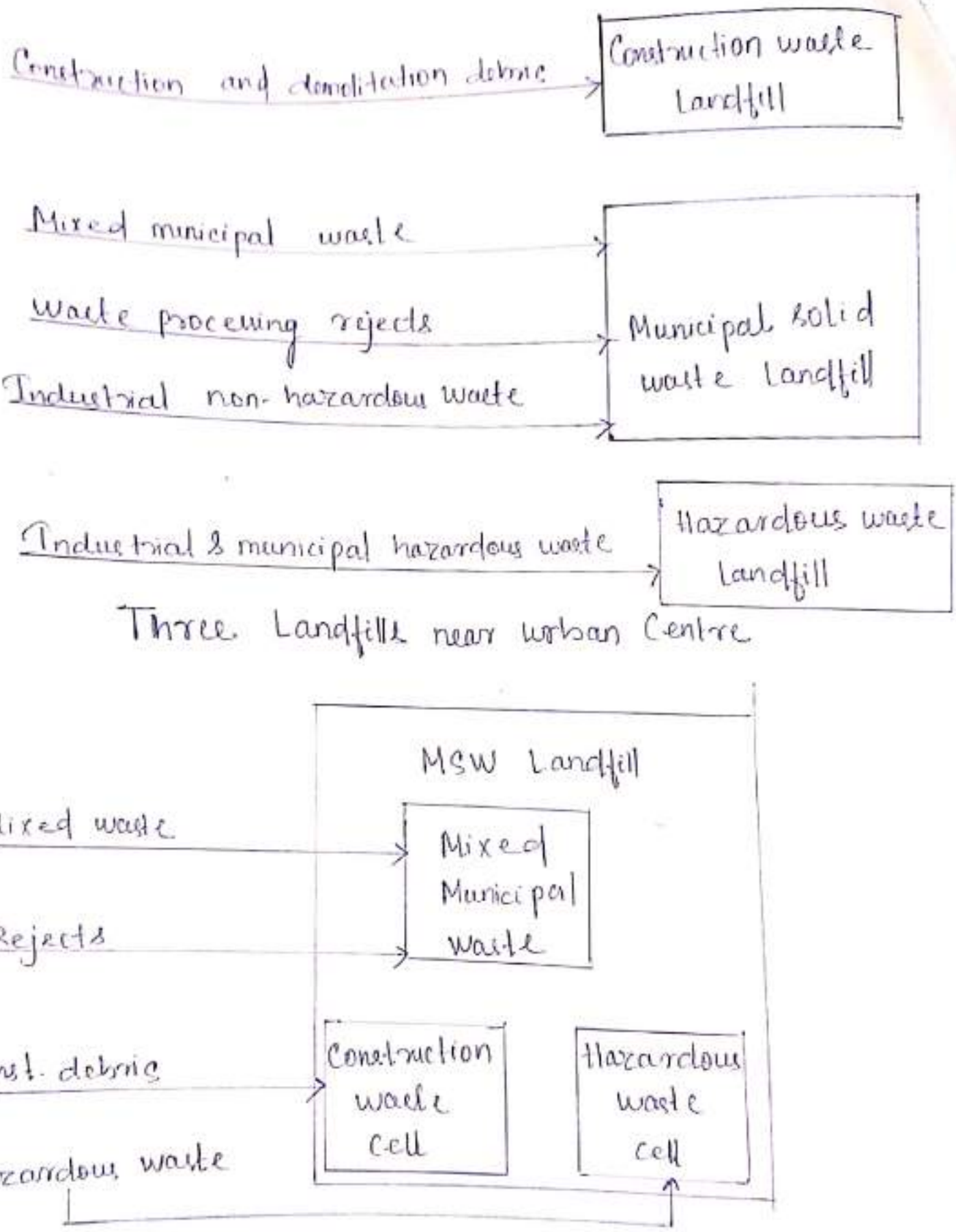
- More waste storage per unit area
- Excavated material used as cover material
- Parks, golf courses, parking lots can be developed on completed Landfill
- Long-term slope stability and erosion control requirements not critical

Disadvantages of below Ground Landfills:

- Regular pumping for leachate collection needed
- Good surface water drainage required

Types of Landfills (For different wastes)

- Hazardous Waste Landfills
- Non-hazardous Waste Landfills
- Inert Waste Landfills / Monofills
- Monofills for high volume waste
- Special Landfills (Including highly toxic / radioactive waste)



Three Landfills near urban Centre

One Landfill near urban Centre

Landfilling Philosophy

- Only that waste should be placed in landfills which has no recoverable component
- Landfills are not designed like bioreactors; all biodegradable wastes should be processed for recovery of materials or energy prior to landfilling.
- The design life of a landfill is typically 50 to 75 years; beyond this life the containment barriers may not perform satisfactory.
- If the waste inside a landfill 'stabilises' within the design life and the emissions from landfill are within limits, then the waste disposal is 'final disposal'; if not then waste disposal is 'temporary storage'.

Planning of Landfills

(a) Design Life
(b) Waste Acceptance
(c) Site Selection
(d) Site Characterisation
(e) Landfill Layout
(f) Landfill Section
(g) Landfill Capacity
(h) Phased Operation
(i) Strategy For Management of Emissions
(j) Design Aspects
(k) Closure & Post-Closure Plan

Definition

Landfills (or Secured landfills, engineered landfills) are Solid waste disposal (or storage) facilities designed with adequate protective measures against.

(a) Ground water pollution,
(b) Surface water pollution,
(c) Air pollution,
(d) Fire hazard,
(e) Birds menace
(f) Pests/rodents
(g) Green house gas emissions
(h) Noise
(i) Dust, wind blown litter
(j) Bad odour
(k) Slope instability and erosion

Types of Landfills
(for different wastes)

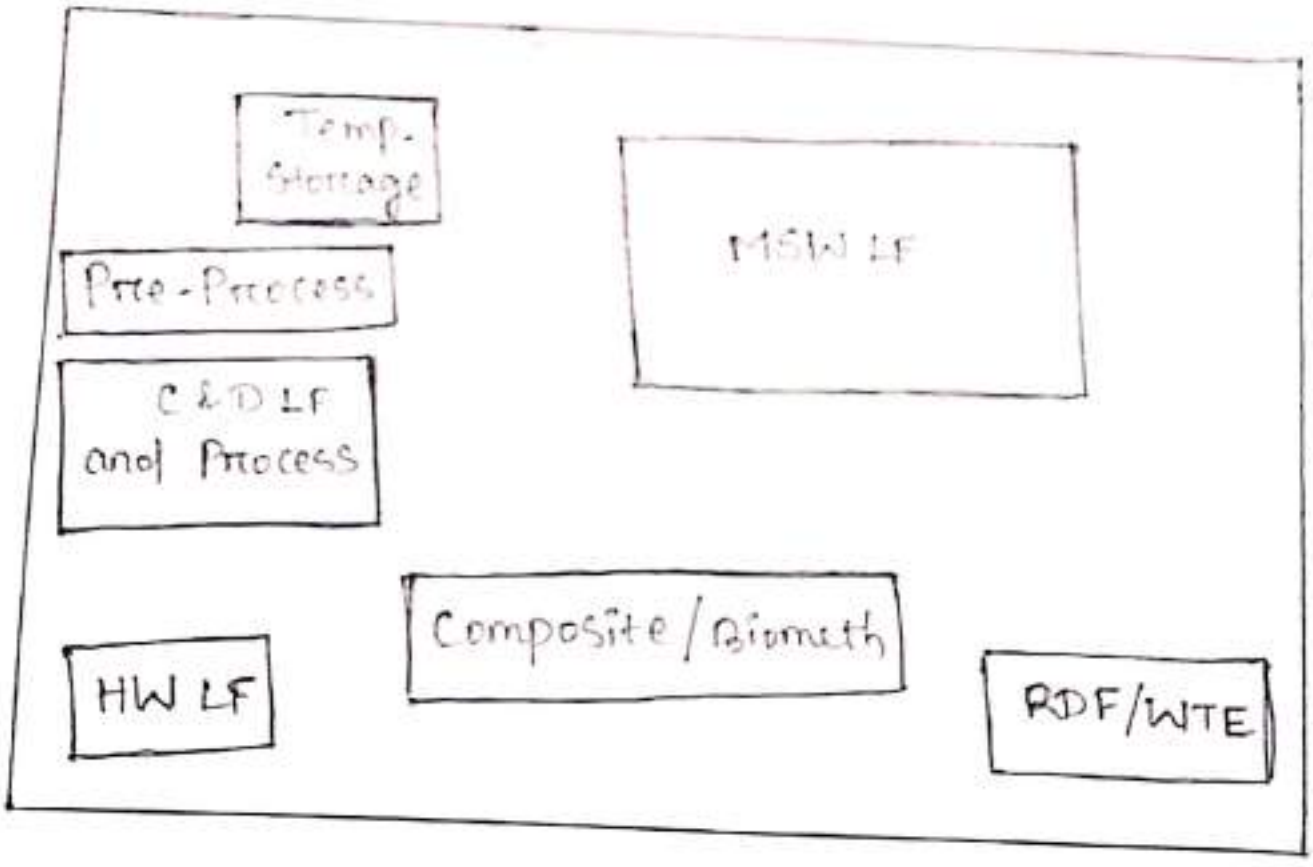
(a) Hazardous Waste Landfills

(b) Non-Hazardous waste Landfills (including MSW Landfills)

(c) Inert Waste Landfills/Monofills
(including Construction & Demolition waste Landfills)

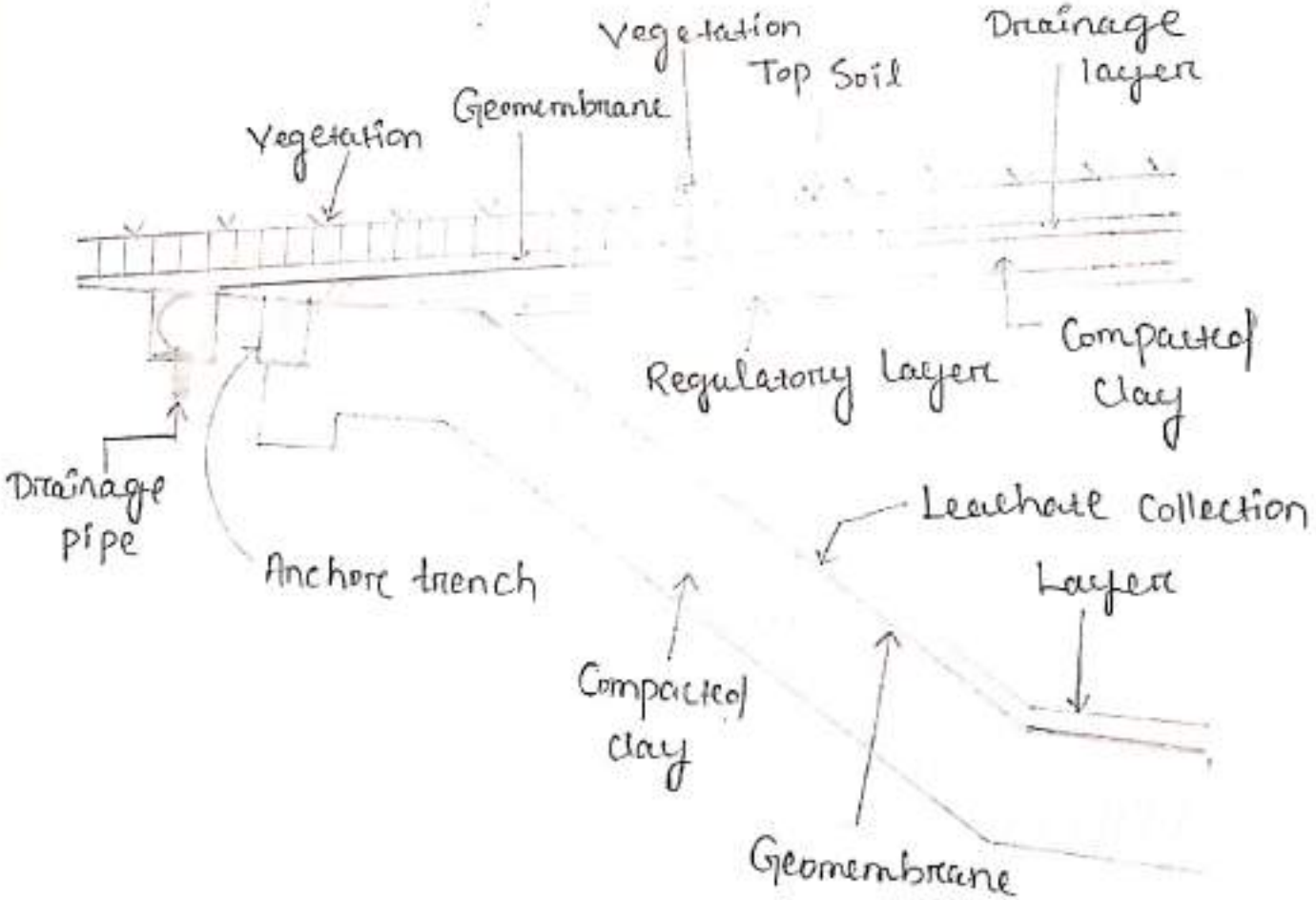
(d) Monofills for high Volume waste
(including Ash ponds, Mine Tailing Ponds)

(e) Special Landfills
(including highly toxic/radioactive waste)



Essential Components of an 'Engineered' or 'Secured' Landfill

(a) A liner system at base and sides of the landfills.
(b) A Leachate collection and control facility.
(c) A gas collection and control facility.
(d) A final cover system at the top of the landfill.
(e) A surface water drainage system.
(f) An Environmental monitoring system.
(g) A closure and post-closure plan.



Design Life

Design Life of Landfill

= Active period + Closure and post closure period

Active Period = 10 to 25 years

Closure and post closure Period = 30 years

Waste Acceptance

(a) Authorised waste only.
(b) No liquid waste or Slurry type waste.
(c) No recyclable waste; no compostable waste.
(d) No waste from which energy or material recovery is feasible through thermal/biological process.
(e) Incompatible wastes in Separate landfill units.
(f) No non-hazadous or municipal waste in HW landfills and no hazadous waste in MSW landfills.
(g) Extremly hazadous wastes should be stabilised before landfilling or disposed in spacially designed waste disposal units.

Site Selection

Objective :

- To select a site with greatest protection to its environment.
- At low cost
- With public acceptance

Factors to be Considered :

- Receptor related attributes
- Pathway related attributes
- Source (waste) related attributes
- Waste management related attributes

Site Selection

Selection process :

- Potential sites are identified
- Site Selection Criteria is drawn up
- Data is obtained
- Weighted Site ranking methodology is adopted

Location Criteria (for lined landfills)

Lake/pond	:	> 200 m (>500m DW)
River	:	>100m
Flood Plain	:	Protective Embankment
Highway	:	>500m
Habitation	:	>500m
Public Park	:	>500m
Critical Habitat	:	No
Wetland	:	No
Coastal regulation Zone	:	No
Airport	:	> 3000 m to 20 km
Water Supply well	:	>500m
Ground water Table Level	:	2m below base of landfill
Others	:	Local needs

Landfill Layout

a) The layout of a landfill in plan is governed by the shape of the area made available for landfilling

b) About 80% of the total area is used for placement of the waste.

c) The balance 20% of the area is covered by the following:

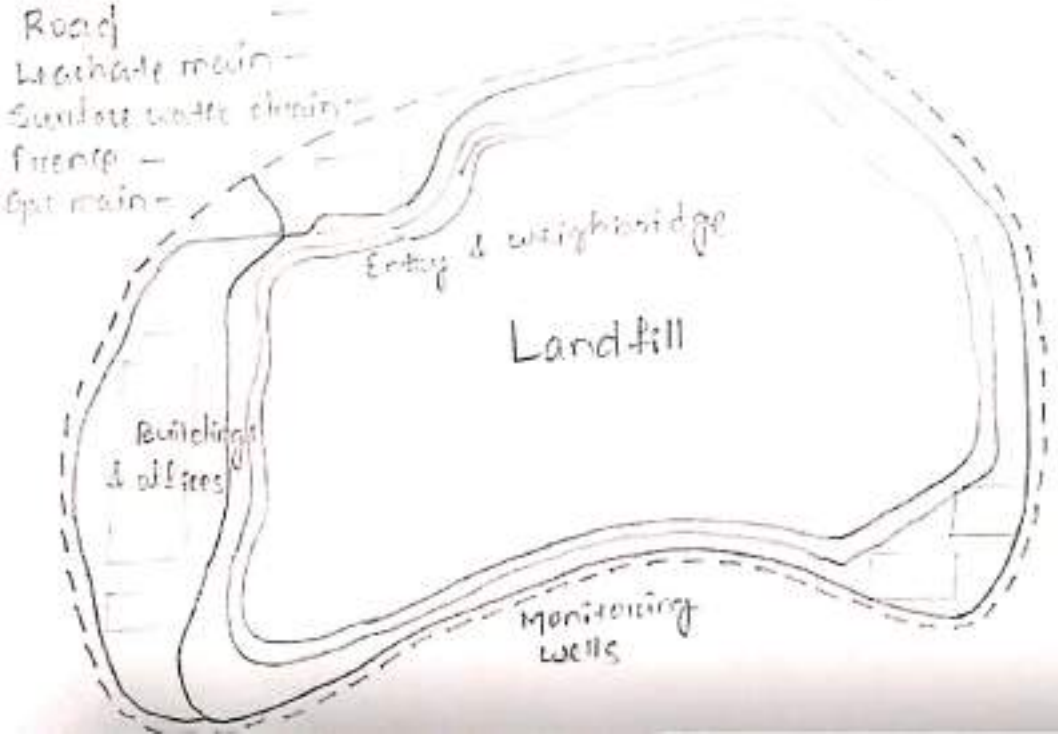
(i) Built-up area - office, laboratory, workshop, equipment shelters, weighing scale

(ii) Treatment facilities, for leachate and gas and pond for storm water detention

(iii) Fencing, green belt, roads, storm water drains

(iv) Temporary holding areas for waste material, Construction materials.

(v) Environmental monitoring facilities.



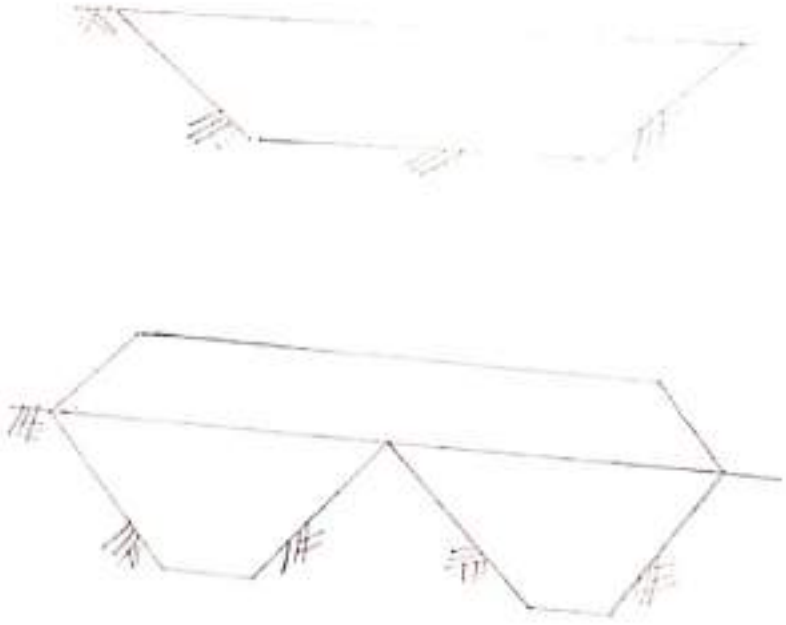
Landfill Section

Factors:

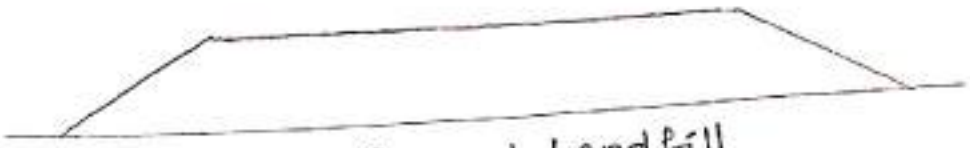
- Topography of the area
- Depth to groundwater table
- Depth to rock
- Availability of liner and cover material

Types:

- Below ground landfills (trench landfills)
- Above ground landfills (area landfills)
- Slope landfills
- Valley landfills (canyon landfills)
- A combination of the above



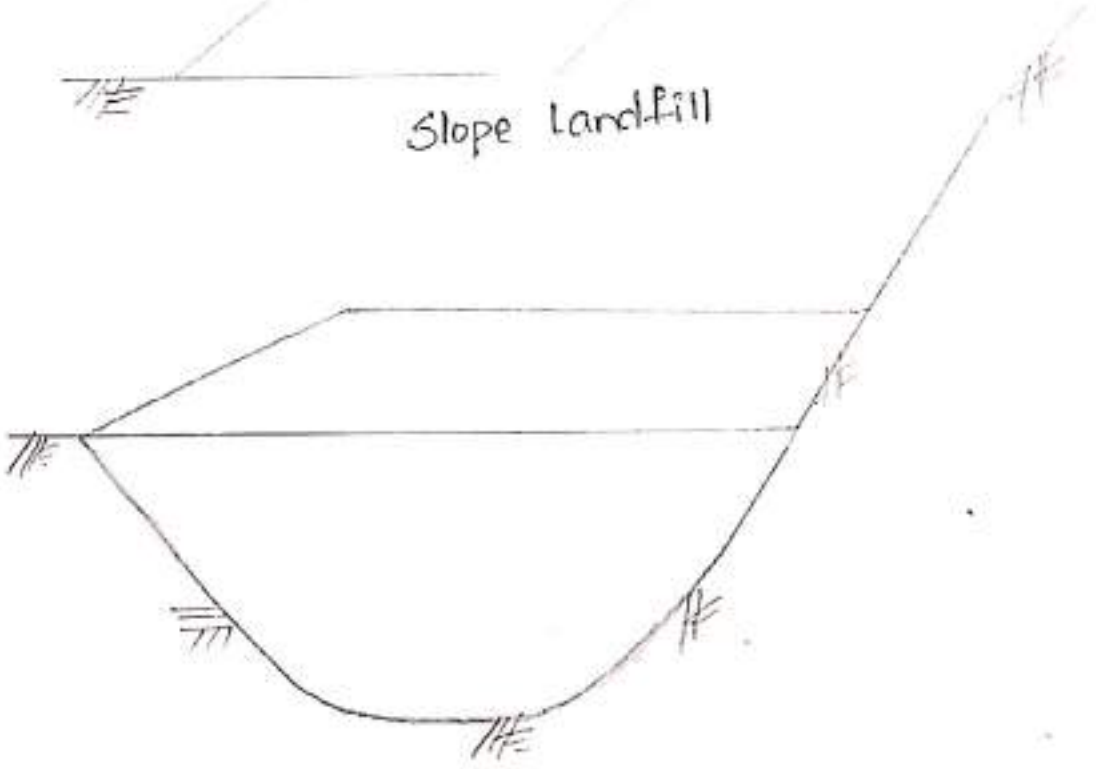
Below ground and trench landfill



Above Ground Landfill

Above and below landfill

Slope Landfill



Valley landfill

Above Ground landfill with Embankments

Above and below Ground landfill with Embankments